Chapter 9

Conclusions and Suggested Future Work

Angle stability control is an old power system problem, with many effective solutions. The present deregulated, competitive environment for the generation subsystem, however, presents new challenges; power transactions may be very different than planned, with need to increase stability-related transfer limits. New long-distance interconnections on several continents present synchronous stability challenges. We wish to exploit recent and emerging technologies for the development of cost-effective advanced stability controls.

Technologies include high voltage power electronics, and the various information technologies such as digital sensors and signal processing, digital controls, digital communications, fiber optics communications, GPS, intelligent controls, and advanced control theory.

Questions investigated by the task force include:

- What is the value and application of wide-area (centralized) stability control?
- What is the value and application of direct control of rotor angles?
- What are needs for adaptive control?
- What new control techniques (examples: robust control theory, fuzzy logic) are promising?

9.1 Conclusions

1. The primary stability controls are fast fault clearing and generator excitation control. Special feedforward controls such as generator tripping for severe disturbances are very effective and are widely used.
2. Generator excitation control and control of other existing actuators should be fully exploited before considering transmission level mechanically-switched or power electronic controlled equipment.
3. The purpose of stability controls is to remove stability-imposed limits on power transfer. High damping ratio for oscillation damping or “stiff” (high synchronizing power) performance may not be cost-effective. Direct control of rotor angle is not normally appropriate.
4. For cost and reliability/complexity reasons, local control strategies are the first choice. Control and communication technologies allow wide-area control where benefits (e.g., superior observability) exist.
5. Digital controls should not be simple replicas of analog controls. Possibilities for control adaptation, control mode shifting, and different control structures should be considered.

6. Time and frequency domain simulations are essential for robust stability control design and for control certification. This requires development of accurate models and data sets. Simulations must include sensitivity analysis of various operating/ disturbance conditions and other uncertainties. Simulations should be validated by field tests and system monitoring.
7. Wide-area monitoring of power plants and substations is desirable to support stability control implementation and operation.
8. Control reliability should not be based on simple redundancy requirements. Rather, hardware and software algorithm failure modes and frequency should be investigated, along with the consequences of failures.
9. With independent ownership of generation, requirements to maintain stability of synchronous generators remain. Overall power *system* engineering for stability is required. Some system requirements should be mandated. One example is generator automatic voltage regulation. Other requirements are suitable for ancillary service arrangements.
10. Transmission-level power electronic equipment offers many possibilities for powerful stability control. These are available for special needs, and ongoing development may make the equipment cost-effective for more widespread use.
11. Synergies are possible between stability control and control center EMS (energy management system) applications. Dynamic security assessment may be used for control arming and adaptation, or as the database for pattern-recognition based controls.
12. "Defense-in-depth" and "multiple lines of defense" are essential to minimize catastrophic power system instability and widespread outages because of rare multiple outages and failures. Stability controls may include load shedding and controlled separation. Power plants should be able to withstand voltage and frequency excursions associated with islanding and other abnormal conditions.

9.2 Areas for Future Work

1. Wide-area control based on new communication technologies. Digital fiber optic communication is rapidly becoming available. Emerging technologies such as low earth orbit satellites are promising. Direct load control is facilitated by information-age technology.
2. Further exploitation of digital control possibilities that break paradigms established during the decades of analog control development.
3. Modulation of steam and gas turbines mechanical power for damping of low frequency oscillations.
4. Integration of control center data/application programs with stability controls. A particular challenge for on-line interarea stability assessment is state estimation for power systems spanning large portions of a continent.

5. Strategies and criteria for stability control in the partially deregulated and restructured electric power industry. This will include better-defined mandatory practices with enforcement, and also ancillary service markets for power system stability enhancing controls.